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TITLE: Display system having multiple memory elements per pixelAbstract Text (1):

A display matrix is provided for forming a composite image from a series of sub-images. The display matrix includes a plurality of display elements, each display element including a pixel, and a display circuit electrically connected to the pixel. Each display circuit includes a plurality of memory cells, and a selector for outputting to the pixel data from one memory cell at a time where the plurality of memory cells are non-addressably connected to the selector.

Brief Summary Text (3):

The invention generally relates to a display system for producing an image and more specifically to a display system for providing a sequentially produced composite image.

Brief Summary Text (5):

A continuing objective in the field of electronics is the miniaturization of electronic devices. Most electronic devices include an electronic display. As a result, the miniaturization of electronic displays is critical to the production of a wide variety of compact electronic devices.

Brief Summary Text (6):

The purpose of an electronic display is to provide the eye with a visual image of certain information. This image may be provided by constructing an image plane composed of an array of picture elements (or pixels) which are independently controlled as to the color and intensity of the light emanating from each pixel. The electronic display is generally distinguished by the characteristic that an electronic signal is transmitted to each pixel to control the light characteristics which determine the pattern of light from the pixel array which forms the image.

Brief Summary Text (7):

Two examples of electronic displays are the cathode ray tube (CRT) and the active-matrix liquid crystal display (AMLCD). There are other electronic displays, but none are so well developed as the CRT and AMLCD which are used extensively in computer monitors, televisions, and electronic instrument panels. The CRT is an emissive display in which light is created through an electron beam exciting a phosphor which in turn emits light visible to the eye. Electric fields are used to scan the electron beam in a raster fashion over the array of pixels formed by the phosphors on the face plate of the electron tube. The intensity of the electron beam is varied in an analog (continuous) fashion as the beam is swept across the image plane, thus creating the pattern of light intensity which forms the visible image. In a color CRT, three electron beams are simultaneously scanned to independently excite three different color phosphors respectively which are grouped into a triad at each pixel location.

Brief Summary Text (8):

In contrast to the emissive type displays such as the CRT, an AMLCD display utilizes a lamp to uniformly illuminate the image plane which is formed by a thin layer of liquid crystal material laminated between two transparent conductive

surfaces which are comprised of a pattern of individual capacitors to create the pixel array. The intensity of the illumination light transmitted through each pixel is controlled by the voltage across the capacitor, which is in turn controlled by an active transistor circuit connected to each pixel. This matrix of transistors (the active matrix) distinguish the AMLCD from the passive matrix liquid crystal devices which are strictly an array of conductors controlled by transistors external to the image area usually in the periphery of the matrix. The ability of each transistor to control the characteristics of just one pixel allows for the higher performance found in AMLCD displays in contrast to the passive arrays.

Brief Summary Text (10):

In most displays, the electronic activation of the image must be continuous or persistent through repetition. In the CRT and emissive displays in general, a constant or highly repetitive source of energy must be applied to the pixel to create photon emission. Phosphor decay times are typically a few milliseconds. Similarly, the capacitors in the AMLCD array lose their charge through leakage and accurate grayscale levels are lost. Furthermore, many liquid crystal materials exhibit ion migration and must be reversed in polarity with each refresh cycle. In general, displays with limited persistence must be refreshed frequently to avoid noticeable brightness variation known as flicker. On the other hand, displays with substantial persistence cannot display moving images without ghost images. Refreshing the image of most displays requires repeated transmission of the image data to the display, either from the broadcast source or from a storage device.

Brief Summary Text (11):

Not all electronic products which contain an electronic display have memory for storing the data which is to be displayed. For instance, a television must activate the CRT display in real time as the broadcast signal is received unless a VCR or similar storage medium is employed. In computers, data is transmitted and stored digitally. Moreover, in portable electronics devices, size and power constraints require the use of semiconductor memory which stores data only in digital format. In digital electronic products, it is typical that a display controller is incorporated to receive and store the bit mapped image to be displayed and then to transfer that data to the display in a series of image frames at a rate high enough to look smooth to the eye. The semiconductor memory storing the image bits is called the frame buffer, and the rate at which the data is refreshed on the display is called the frame rate.

Brief Summary Text (12):

It is an advantage in many applications to display large amounts of information requiring more and more resolution in the display. High resolution displays may contain hundreds of thousands of pixels. As an example, the Super VGA (SVGA) display resolution consists of 480,000 pixels. With a simple monochrome image and no grayscale, the frame storage is only equal to the approximately one-half megabit frame size. However, were the image to be full 24 bit depth color (i.e., 3 colors and 8 bits of grayscale per color), the frame storage would approach 12 megabits. At the frame rates which are common today for high performance displays, at least 60 frames per second and up to 85 frames per second, as many as one gigabits per second must be transferred from the frame buffer to the display. The state of semiconductor technology at present limits clock speeds to a level well below such transfer rates and parallel interfaces of 16 to 32 bit widths are typical in high performance displays.

Brief Summary Text (13):

It is a characteristic of analog displays that when the image data is stored in semiconductors, the digital information is converted to analog in a digital-to-analog converter (DAC) at the interface of the display. The digital representation of a pixel at the high standard of 8 bits of grayscale allows the creation of 256 separate shades per color (16 million distinct colors). In high performance displays, multiple DAC channels are required to provide the bandwidth of data

transfer required.

Brief Summary Text (14):

As was noted above, most displays must be frequently rewritten to maintain an image. In the case of both CRT and AMLCD displays, data is being rewritten to one part of the display area while the rest of the array continues to display the prior image frame. This property is particular to monochrome displays and to color images are created from a composite of spatially separated sub-pixels. There is a clear advantage to writing and displaying data at the same time allowing each function to make maximum utilization of time allowed for each frame.

Brief Summary Text (15):

Once data corresponding to an image is transferred to a display via electronic signals, there is an advantage to the display device being able to maintain the image unless a portion of the image must be altered to provide motion to the image. The amount of data written to the display in each subsequent frame can be substantially reduced if the writing operation is organized to be random, such as to write data to any location in the array and only to those locations where the data is changing for reasons that the image is moving or for reasons the array is reused sequentially to create a composite image. To achieve this end however, pixel locations which are not being rewritten must be able to store data and continually display it.

Brief Summary Text (17):

Similarly, in an active matrix display a multiplicity of transistors may be provided in correspondence to each pixel such that a static memory (SRAM) cell (typically four or six transistors) can be utilized to activate each pixel. There are several advantages to static memory such as the on-state output voltage always being at the rail voltage, the low activation current, no voltage decay, and sufficient signal to noise to read from the memory cells any stored data. However, because a static memory cell is itself bistable, the pixel activation will provide no analog grayscale.

Brief Summary Text (18):

In general, displays with no analog response fall into two categories. Those displays with an extremely fast response in relation to the time divisions of the on-off cycles (as is typical of MEMS devices) can achieve grayscale through pulse width modulation. Those displays with a relatively slow response time in relation to on-off cycles (as is typical of liquid crystal devices) can achieve grayscale through a root mean square (RMS) voltage level based on the average time-voltage product. In both cases however, there is a disadvantage in comparison to analog grayscale methodologies, that being the loss of parallelism of the data transfer of the grayscale bits. Data transfer rates from frame buffers to a binary display device can be significantly higher than an analog display.

Brief Summary Text (19):

In the particular case of miniaturization of high resolution electronic displays, there is an advantage to reducing the size of the pixels which comprise the display. The need for such small devices has led to the development of a category of miniature displays often described as microdisplays with pixel sizes as small as 10 microns. In order to achieve this pixel resolution, active matrix devices have been developed utilizing silicon wafer fabrication of CMOS devices as opposed to thin-film transistors fabricated on a glass or quartz substrate. Single crystal silicon design rules are many times smaller than poly-silicon resulting in transistor sizes to easily fit microdisplay geometries. With the exception of techniques to separate the single crystal transistors from the silicon substrate utilizing lift-off technology, CMOS based active matrix displays are inherently opaque, and therefore must be reflective rather than transmissive like the poly-silicon devices. Even thin film transistor (TFT) based transmissive devices are however also opaque where transistors and interconnection lines, and optical

efficiencies are very low for high resolution TFT displays.

Brief Summary Text (21):

The pixel sizes are also small relative to the size of color filters used in TFT AMLCD displays to create color triads for each pixel. There is a significant advantage to creating color through the sequential use of the entire array to create an image specific to each of the three prime color components. Through the utilization of separate light emitting diodes of each prime color to illuminate the display, the diodes can be turned rapidly on and off to correspond to the particular color component being displayed by the array at that moment. This method of color creation is called field sequential color wherein each color field is sequentially illuminated by the appropriate diode.

Brief Summary Text (22):

An important limitation of the field sequential color method is that data for the next color field cannot be written while the current color field is being illuminated. As a result, the time available to write to the display is limited and must be substantially less than the time allowed to illuminate each particular field's color.

Brief Summary Text (23):

Because at least three different color images need to be displayed at a rate faster than can be resolved by the eye, the field sequential color method at least triples the frame rate required as compared to a monochrome display.

Brief Summary Text (24):

A need exists for a display system which can overcome the various above-described limitations of prior art display systems and be able to produce a high resolution field sequential color image which is not limited by the frame transfer rate limitations of existing display matrices. The display system should also be adaptable for use as a microdisplay.

Brief Summary Text (25):

A significant aspect of a compact electronic device is its portability. It is impractical and disadvantageous for a compact electronic display to rely on an external power source. Rather, compact electronic displays must rely on an internal battery for energy. It is important to the usefulness and reliability of the electronic display that the display be energy efficient so that the battery life of the display is optimized. A need thus exists for an energy efficient display for use in portable electronic devices.

Brief Summary Text (26):

These and other advantages are provided by the display system of the present invention.

Brief Summary Text (28):

A display matrix is provided for forming a composite image from a series of sub-images. In general, the display matrix includes a plurality of display elements, each display element including a pixel, and a display circuit electrically connected to the pixel. Each display circuit includes a plurality of memory cells, and a selector for outputting to the pixel data from one memory cell at a time.

Brief Summary Text (29):

According to one aspect of the display matrix of the present invention, a plurality of memory cells in the display circuit are continuously electrically connected to the selector of the display circuit at the same time. As a result, there is no need to address a particular memory cell to a particular selector. This may be accomplished, for example, by the display circuit including separate conductive elements for each memory cell in the display matrix which electrically connects a memory cell to the selector in the display circuit.

Brief Summary Text (30):

According to another aspect of the display matrix of the present invention, the display matrix is formed on a substrate having a plurality of regions where each region includes a memory circuit with a plurality of memory cells, and a selector electrically connected to the plurality of memory cells in the region. The substrate may be any material on which the display circuit may be attached or formed. In a preferred embodiment, the substrate is a semiconductor, such as silicon, on which the display circuits are formed by one or more of a variety of methods known in the art.

Brief Summary Text (31):

According to this aspect, the memory cells are physically interdispersed among the selectors within the plurality of display elements. In this regard, the memory associated with the display matrix is integrated into the display matrix as opposed to be external to the display matrix and the selectors.

Brief Summary Text (32):

According to the present invention, at least a portion of the display circuits of the display matrix include at least 2 memory cells per display circuit. In one embodiment, at least a portion of the display circuits of the display matrix include at least 3 memory cells per display circuit. The display matrix may optionally include 4-18 or more memory cells per display circuit, depending on a variety of factors which will be discussed herein.

Brief Summary Text (33):

In a preferred embodiment, the display matrix has sufficient memory such that data can be transferred to the display matrix for one sub-image while a different sub-image is displayed. The display matrix may also have sufficient memory to display two or more different sub-images without having to write to the memory cells between displaying the different sub-images. The plurality of memory cells in each circuit can represent different bits of a digital grayscale value. It is possible to vary the digital grayscale value significance of a particular memory cell image to image and field to field. The plurality of memory cells in each circuit can represent bits of different color fields.

Brief Summary Text (34):

In one embodiment, the display circuit can be operated in a field sequential color (FSC) mode without having to write to the memory cells between displaying different fields. This enables the display matrix to not need an external frame buffer. The display matrix may optionally be configured to be operated in a field sequential color (FSC) mode without having to write to the memory cells between displaying different fields.

Brief Summary Text (36):

In one embodiment, the display matrix is sized to form a microdisplay. According to this variation, the pixels in the plurality of display elements may form a source object having an area equal to or less than about 400 mm.² and preferably between about 20 mm.² and 100 mm.². The pixels of the display matrix preferably have an area less than about 0.01 mm.² and more preferably between 50 .mu.m.² and 500 .mu.m.².

Brief Summary Text (37):

The present invention also relates to a display system which includes a display matrix according to the present invention and peripheral control circuits for controlling read and write operations to the memory cells. The display system may also include an illumination source for illuminating the pixels. In one embodiment, the display includes a light emitting mechanism provided at each pixel. The display system may also include a light modulating mechanism, such as a liquid crystal material, provided at each pixel.

Brief Summary Text (38):

The display system may optionally further include logic for reading, inverting and rewriting data stored in the memory cells to provide a refresh cycle, a processor for reading, modifying, and rewriting data stored in the memory cells to compose a bit mapped image without the need of an external frame buffer, control circuits for reading, modifying, and rewriting data stored in the memory cells to provide a cursor function. The peripheral control circuits may also serve to read, move, and rewrite data stored in the memory cells to provide a scroll function.

Brief Summary Text (39):

The display system may also include an illumination source capable of providing a plurality of different color illumination to the pixels, the particular color illumination provided to the pixels being coordinated by the peripheral control circuits with the read and write operations to the memory cells. The illumination source preferably provides at least three different colors of illumination. Two different colors of illumination or more than three different colors of illumination may also be provided.

Brief Summary Text (40):

The display matrices and display systems of the present invention may be used in a display component of a variety of electronic devices. Examples of such devices include, but are not limited to portable computers, personal communicators, personal digital assistants, modems, pagers, video and camera viewfinders, mobile phones, and television monitors. In one particular embodiment, the display matrices and display systems of the present invention are used in combination with one or more magnification optics to form a virtual image display system.

Brief Summary Text (41):

The present invention also relates to methods of using the display matrices and display systems of the present invention to produce composite images as described herein.

Drawing Description Text (2):

FIG. 1 illustrates a display matrix.

Drawing Description Text (3):

FIG. 2 illustrates a display circuit which may be used in the display matrix of the present invention.

Drawing Description Text (4):

FIG. 3 illustrates a prior art display circuit.

Drawing Description Text (7):

FIG. 5 illustrates a backplane integrated circuit (backplane IC) which may be used in a display matrix of the present invention.

Drawing Description Text (8):

FIGS. 6A-6C illustrate three examples of a virtual image display which include a display matrix according to the present invention, and one or more magnification optics.

Drawing Description Text (9):

FIG. 6A illustrates a virtual image display system which includes a display matrix which projects an image onto a back surface of the first magnification optic which reflects (at least partially by total internal reflection) the image to a surface having a magnification function and a reflection function.

Drawing Description Text (10):

FIG. 6B illustrates a virtual image display system which includes an illumination

source which reflects light off the microdisplay system to a beamsplitter which reflects an image formed by the microdisplay to a surface of the first magnification optic having a magnification function and a reflection function.

Drawing Description Text (11):

FIG. 6C illustrates a virtual image display system which includes an illumination source which reflects light off the microdisplay system to a back surface of a first magnification optic which reflects the light to a beamsplitter which reflects the light to a surface of the first magnification optic having a magnification function and a reflection function.

Drawing Description Text (12):

FIG. 7A illustrates the data transfer and display sequence of a prior art display matrix which employs a single memory cell per pixel.

Drawing Description Text (13):

FIGS. 7B and 7C illustrate data transfer and display sequences that may be used when a display matrix according to the present invention which employs two or more memory cells per pixel is operated in an FSC mode.

Drawing Description Text (14):

FIG. 7B illustrates that it is possible to display multiple sub-images of a frame, optionally all the sub-images of a frame, without having to transfer any data into memory.

Drawing Description Text (15):

FIG. 7C illustrates that it is possible to display one sub-image while transferring data for another sub-image into memory.

Detailed Description Text (2):

The present invention relates to a display matrix for forming sequentially formed composite images. As used herein, a sequentially formed composite image is an image formed by displaying a series of two or more different sub-images to an observer where the different sub-images are displayed one sub-image at a time on the display matrix. These display matrices can be used in a display system component of a variety of electronic devices. Examples of such devices include, but are not limited to portable computers, personal communicators, personal digital assistants, modems, pagers, video and camera viewfinders, mobile phones, and television monitors. In one particular embodiment, the display matrices and display systems of the present invention are used in combination with one or more magnification optics to form a virtual image display system.

Detailed Description Text (3):

A unique property of the display matrix of the present invention is that data for a plurality of sub-images may be stored in the display matrix simultaneously. This property eases the instantaneous bandwidth requirements of the display matrix and, in certain situations, actually decreases the amount of data which must be transferred to the display matrix from external memory locations.

Detailed Description Text (4):

In general, a display system forms a sequentially formed composite image by displaying a series of sub-images to an observer at a rate preferably faster than the eye of the observer can resolve. Image quality is reduced if the eye is able to perceive an individual field sub-image, a phenomena known as flicker. In practice, it has been found that frame rates in excess of 60 Hz are necessary to avoid flicker.

Detailed Description Text (5):

Ideally, the data for any sub-image should be present in the display matrix from the beginning until the end of the display of the sub-image. If the display matrix

houses only a single sub-image at a time, then ideally the entire data transfer should take place between the display of one sub-image and the next. This places high instantaneous bandwidth requirements on the system in order to transfer all of the data for a sub-image in the interval between the display of sub-images.

Detailed Description Text (6):

FIG. 1 illustrates a typical display matrix 12 which includes a plurality of display elements 14. Each display element 14 includes a pixel 16 and a display circuit 18 which is electrically connected to the pixel and controls the operation of the pixel 16. As used herein, a pixel refers to any mechanism which can be modulated in response to an electrical field to form a portion of a source object. The plurality of pixels incorporated into the plurality of display elements together form the source object formed by the display matrix 12.

Detailed Description Text (7):

In a display matrix according to the present invention, the display circuit consists of a plurality of memory cells and a selector. The selector is able to output to the pixel the contents of at most one memory cell at any instant. The selector is controlled by additional input signals provided to the display circuit.

Detailed Description Text (8):

FIG. 2 illustrates a display circuit 18 which may be used in the display matrix of the present invention. As illustrated, the display circuit 18 includes a plurality of memory cells 20A, 20B (two shown) which are each electrically connected to a selector 22. The selector controls which memory cell is electrically connected to the pixel 16. As illustrated, the display circuit 18 can also optionally receive one or more inputs 24 for controlling the operation of the selector 22.

Detailed Description Text (9):

As illustrated in FIG. 2, a feature of the display circuit and display matrix of the present invention is that a plurality of the memory cells in the display circuit are continuously electrically connected to the selector of the display circuit at the same time. As a result, there is no need to address a particular memory cell to a particular selector. This may be accomplished, as illustrated in FIG. 2, by the display circuit including separate conductive elements 21 for each memory cell in the display matrix which electrically connects a memory cell to the selector in the display circuit. The figure illustrates that all the memory cells in the display circuit are connected. It is noted that less than all of the memory cells may optionally be continuously electrically connected.

Detailed Description Text (10):

A further feature of the display circuit and display matrix of the present invention is that the display matrix is formed on a substrate having a plurality of regions where each region includes a memory circuit with a plurality of memory cells, and a selector electrically connected to each memory cell in the region. For example, FIG. 1 illustrates a plurality of display circuits in separate regions. By having a plurality of regions which each include a complete memory circuit, a display matrix is provided where the memory cells are physically interdispersed among the selectors within the display matrix. This distinguishes the display matrix of the present invention over prior art displays with an external frame buffer. The substrate may be any material on which the display circuit may be attached or formed. In a preferred embodiment, the substrate is a semiconductor, such as silicon, on which the display circuits are formed by one or more of a variety of methods known in the art.

Detailed Description Text (11):

Yet a further feature of the display matrix of the present is its ability to store more than one image at a time. Because the display circuit 18 has more than one memory cell per pixel, it is possible to display two or more different sub-images

without having to write to the memory cells between displaying the different sub-images. In addition, data may be transferred to the display matrix for one sub-image while a different sub-image is displayed. Accordingly, the data transfer time for one sub-image can be spread over the entire display time of a different sub-image. This alleviates the need for a high instantaneous bandwidth or a high sub-image display rate, a clear advantage over prior art display systems.

Detailed Description Text (12):

FIG. 3 illustrates a prior art display circuit. As illustrated in FIG. 3, the prior art display circuit includes a single memory cell 20C which is connected to pixel 16. The prior art display circuit thus does not need a selector or input for controlling the operation of the selector. Further, because the display circuit only includes one memory cell 20C, a memory matrix employing this display circuit can only store data for one sub-image and thus cannot display different sub-images without having to write to the memory cells between displaying the different sub-images. When it is necessary to create an image out of a composite of sub-images, the sub-images are typically composed in a spatial relationship and written simultaneously to the matrix.

Detailed Description Text (13):

The display matrix of the present invention may be any addressable display which includes a pixel and a display circuit which controls the operation of the pixel in response to control signals. As used herein, a pixel (a contraction of picture element) refers to any mechanism which can either emit light or modulate incident light in response to an electrical field to form one element of a source object. The plurality of pixels incorporated into the plurality of display elements together form the source object formed by the display matrix.

Detailed Description Text (15):

In one embodiment of the present invention, the pixels used in the display matrix are sized to be a microdisplay. As used herein, a microdisplay refers to a display matrix which is used in a virtual image display system to form a source object which is then magnified by one or more magnification optics to form a magnified virtual image. In a preferred embodiment, the microdisplay forms a source object having an area equal to or less than about 400 mm.^{sup.2}. In one embodiment, the source object has an area between about 10 mm.^{sup.2} and 400 mm.^{sup.2}, more preferably between about 20 mm.^{sup.2} and 100 mm.^{sup.2}. The pixels of the display matrix preferably have an area less than about 0.01 mm.^{sup.2} and more preferably between 50 .mu.m.^{sup.2} and 500 .mu.m.^{sup.2}.

Detailed Description Text (16):

By designing a microdisplay to include a display circuit according to the present invention, microdisplays with reduced instantaneous bandwidth requirements and reduced average bandwidth are provided. The reduced bandwidth requirements translate into lower power consumption, which is particularly important for battery-powered applications in devices which incorporate microdisplays.

Detailed Description Text (17):

In one particular embodiment, a microdisplay is provided which includes a liquid crystal device (LCD) and operates in either reflective or scattering modes. FIG. 4A illustrates a cross-sectional view of a liquid crystal device while FIG. 4B illustrates a top-down view of a liquid crystal device. As illustrated in FIGS. 4A and 4B, the LCD 32 is composed of a substrate 34 having a plurality of electrodes 36 corresponding to pixels, liquid crystal 38 arranged on the substrate 34, and a counter electrode 40 arranged on the liquid crystal 38. The liquid crystal is caused to align or relax at each pixel in response to local electric fields applied across the liquid crystal between the pixel and the counter electrode. The potential at each pixel on the substrate is determined by the corresponding display circuit, the design of which is the subject of the present invention. Sequentially changing the potentials at any or all of the pixels on the substrate via the

corresponding display circuits causes the LCD as a whole to form a composite image when properly illuminated.

Detailed Description Text (19):

FIG. 5 illustrates a backplane integrated circuit (backplane IC) which may be used in a display matrix such as a LCD microdisplay. As illustrated, the backplane IC 42 integrates into a single electronic circuit a display matrix 44, programmable registers 46 that generate the control signal logic 48 provided to the display matrix 44 and other timing functions, and an interface 50 to a source of image data. A display matrix for this backplane IC may be sized to include an 800 by 600 two-dimensional array of display circuits.

Detailed Description Text (20):

The display circuit for a backplane IC according to the present invention is composed of two or more memory cells and a selector circuit. The memory cells may be conventional Static Random Access Memory (SRAM) cells composed of six transistors each, though the use of other digital memory cells is intended to fall within the scope of the present invention.

Detailed Description Text (23):

The selector is accomplished with switches that connect the SRAM cells to the pixel at the output of the display circuit. The switches may be pass gates controlled by RED STROBE, GREEN STROBE, and BLUE STROBE signals, respectively. When the RED STROBE signal is asserted, the voltage stored in the RED CELL is transferred to the pixel. The GREEN STROBE and BLUE STROBE signals operate analogously. The various WORD and STROBE signals are provided to each display circuit based on programmable registers inside the backplane IC but outside the display matrix.

Detailed Description Text (24):

When the RED STROBE is asserted over the entire display matrix, a voltage pattern corresponding to the data stored in the RED CELL of every display circuit is output on the pixels. The GREEN STROBE and BLUE STROBE signals operate analogously.

Detailed Description Text (25):

The display matrix of the present invention can be designed to be employed in a wide variety of electronic devices in which a real or virtual image needs to be displayed. In particular, the display matrix is intended for use in small sized electronic devices such as portable computers, personal communicators, personal digital assistants, modems, pagers, video and camera viewfinders, mobile phones, television monitors and other hand held devices.

Detailed Description Text (26):

In one particular embodiment, the display matrix is employed in a virtual image display system where the display matrix forms a source object which is then magnified by one or more magnification optics. In this embodiment, the display matrix is preferably sized to be a microdisplay.

Detailed Description Text (27):

FIGS. 6A-6C illustrate three examples of a virtual image display which include a display matrix according to the present invention, and one or more magnification optics.

Detailed Description Text (28):

FIG. 6A illustrates a virtual image display system which includes a display matrix 62 which projects an image onto a back surface 63 of the first magnification optic 64 which reflects (at least partially by total internal reflection) the image to a surface 65 having a magnification function and a reflection function. The surface 65 reflects the image to a second magnification optic 66 and to an observer 67.

Detailed Description Text (29):

FIG. 6B illustrates a virtual image display system which includes an illumination source 69 reflects light off the microdisplay system 62 to a beamsplitter 71 which reflects an image formed by the microdisplay to a surface 73 of the first magnification optic 64 having a magnification function and a reflection function. The surface 73 reflects the image through the beamsplitter 71 to a second magnification optic 66 and to an observer 67.

Detailed Description Text (30):

FIG. 6C illustrates a virtual image display system which includes an illumination source 75 which reflects light off the microdisplay system 62 to a back surface 77 of a first magnification optic 64 which reflects the light to a beamsplitter 79 which reflects the light to a surface 81 of the first magnification optic 64 having a magnification function and a reflection function. The surface 81 reflects the light through the beamsplitter 79 to a second magnification optic 66 and to an observer 67. Examples of virtual image display systems which can be used include but are not limited to the virtual image display systems described in U.S. Pat. Nos.: 5,625,372; 5,644,323; and 5,684,497 which are each incorporated herein in their entirety by reference.

Detailed Description Text (31):

One feature of the present invention is the efficiency with which the display matrices of the present invention may be operated in a field sequential color (FSC) mode. In a typical FSC mode, a composite image is formed through the repetition of a sequence of different color sub-images, typically red, green, and blue sub-images. As illustrated in FIGS. 7A and 7B, the color corresponding to a particular sub-image 26 is called a field 28. A single sequence of the different fields is called a frame 29.

Detailed Description Text (33):

Data transfer requirements for an FSC mode are more stringent than for a general system for sequentially formed composite images. The total length of time that a sub-image may be displayed, from the end of the display of the prior sub-image to the end of the display of the current sub-image, is limited by the minimum frame rate necessary to avoid flicker. The data for a particular sub-image must also be present in the display matrix from the beginning to the end of the sub-image. The quality of the image produced is reduced if part of the one color frame is displayed while a part of another color frame is displayed.

Detailed Description Text (34):

FIG. 7A illustrates the data transfer and display sequence of a prior art display matrix which employs a single memory cell per pixel. As illustrated, the entire data transfer for a sub-image takes place during a time period $T_{sub.DT}$ after the time period for displaying the prior sub-image $T_{sub.DI-1}$ and before the time period for displaying the current sub-image, also $T_{sub.DI-2}$. In order to avoid flicker, the period of time available for data transfer and display is limited by the minimum frame rate $T_{sub.MFR}$. The need to transfer the entire data for a sub-image during the time period $T_{sub.DT}$ which is less than the minimum frame rate $T_{sub.MFR}$ time period creates a high instantaneous bandwidth requirement on a prior art display matrix operating in an FSC mode. The average bandwidth requirement, which is a direct function of the frame rate as well, is accordingly high.

Detailed Description Text (35):

FIGS. 7B and 7C illustrate data transfer and display sequences that may be used when a display matrix according to the present invention which employs two or more memory cells per pixel is operated in an FSC mode. When a display matrix employs two or more memory cells per pixel, it is possible to store data for more than one sub-image, whether of the same or a different field. In one embodiment, the display matrix includes sufficient data to store all of the individual sub-images of a field or the entire composite image simultaneously.

Detailed Description Text (36):

As illustrated in FIG. 7B, by having sufficient memory to store multiple sub-images, it is possible to display multiple sub-images of a frame, optionally all the sub-images of a frame, without having to transfer any data into memory. Alternatively, as illustrated in FIG. 7C, by having sufficient memory to store multiple sub-images, it is possible to display one sub-image while transferring data for another sub-image into memory. As discussed herein, the ability to display one sub-image while transferring data for another sub-image into memory enables one to produce more colors and other visual effects than would otherwise be possible due to the greater instantaneous bandwidth requirement of prior art display matrices operated in an FSC mode.

Detailed Description Text (37):

As demonstrated by the data transfer and display sequences illustrated in FIGS. 7B and 7C, the use of two or more memory cells per pixel in a display matrix significantly reduces the instantaneous bandwidth requirement of the system. In addition, in the case where the data for one particular field sub-image is the same as the that for the next sub-image of the same field, the data for the next sub-image does not need to be transferred at all, reducing the average bandwidth requirement.

Detailed Description Text (38):

The present invention is intended to encompass display matrices where each memory cell consists of one bit or more than one bit of memory. As used herein, a digital display system refers to a display system where a single binary bit of memory is associated with each memory cell. In this system, the selector outputs a binary value as a function of the data stored in the memory cells, and binary control signals are provided to each display circuit. By binary is meant a two-level voltage system, where each voltage can be represented by either a '0' or a '1'.

Detailed Description Text (39):

In a digital display system, gray levels within a particular color field may be attained by multiplexing different sub-images of that field. By showing certain sub-images of a field longer than other sub-images, certain sub-images are rendered more significant to the composite field image than other sub-images. For instance, in a display matrix with two memory cells per display circuit, the first memory cell in each display circuit may correspond to the most significant bit (MSB) of the binary representation of the grayscale values for a particular field. The second memory cell in each display circuit may correspond to the least significant bit (LSB). In a display matrix with three memory cells per display circuit, the first memory cell may be the most significant bit (MSB), the second memory cell the second significant bit (SSB), and the third memory cell the least significant bit (LSB).

Detailed Description Text (40):

By displaying each bit for different portions of the time that a particular frame is displayed, a multiple grayscale field may be formed. One bit may be displayed for a larger portion of the time that a particular frame is displayed either by displaying that bit longer, as illustrated in FIG. 8A, or by displaying that bit more frequently, as illustrated in FIG. 8B. For example, a four-level grayscale system is achieved in a two bit system when the MSB sub-image is displayed for twice as long as the LSB sub-image. The total display time for both sub-images equals the display time for the field.

Detailed Description Text (43):

In one embodiment of the present invention, two memory cells are present in each display circuit. Once data has been loaded into the display matrix, it is possible to form either a dichromic composite static image or a four-level grayscale monochromic composite static image. In the dichromic case, one memory cell of each display circuit contains the data corresponding to one color field and to the

location of the display circuit within the image. The second memory cell contains the corresponding data for the second field. By cycling between the two sub-images corresponding to the memory cells within each display element, a dichromic composite static image is formed.

Detailed Description Text (44):

In the four-level grayscale case, the memory cells of each display circuit contain the MSB and LSB of the image data associated with a single color field. By cycling between the two corresponding sub-images, while keeping the total duration of the MSB image twice that of the LSB image, four levels of grayscale are achievable.

Detailed Description Text (45):

It is noted that in both the dichromic and four-level grayscale cases, if the image is static, there is no need to load data into memory more than once. A display system of the present invention just continues cycling between the two sub-images to achieve the intended effect. Data is only reloaded when the image content changes. In contrast, in a prior art display system with only a single binary memory element in each display circuit, data would have to be loaded in with every sub-image, for both the dichromic and four-level grayscale cases, regardless of whether the image content had changed. Even if the sole memory element were analog, data would still have to be loaded in with every sub-image for the dichromic case.

Detailed Description Text (46):

In analogy with the two cell case, with three memory cells present in the display circuit, a three-color composite image and an eight-level grayscale monochromic composite image are possible with data reloading not necessary until the image content changes. With four memory cells, three basic cases are possible: (1) a four-color composite image; (2) a dichromic composite image with four levels of grayscale in each color; and (3) a 16-level grayscale monochromic composite image.

Detailed Description Text (47):

In analyzing display circuits with more than four memory cells, many permutations of numbers of color fields and grayscale levels are possible and are all intended to fall within the scope of the present invention. If the analysis is confined to typical display systems operating in an FSC mode with three fields, some of the interesting display circuits are those with (1) six memory cells for four levels of grayscale per field; (2) nine memory cells for eight levels of grayscale per field; (3) twelve memory cells for 16 levels of grayscale per field; and (4) eighteen memory cells for 64 levels of grayscale per field.

Detailed Description Text (48):

In general, each memory cell in a display circuit of the present invention corresponds to a sub-image. The sub-images corresponding to different memory cells are output from the display matrix according to the control signals provided to each display circuit. The sub-images can have any order and may be displayed for any amount of time. For example, a particular sub-image may be displayed more frequently than other sub-images, as in the case of the MSB sub-image. The sub-image may also be displayed for a longer period of time than other sub-images.

Detailed Description Text (49):

The assignment of sub-images to different memory cells may be dynamic. In a system with three bits of memory for display element, the assignment of the first, second, and third memory cells as the MSB, SSB, or LSB can be changed, field to field and/or frame to frame. For example, the first memory cell of every display element may at one time be assigned to the MSB sub-image of the red field and at another time to the LSB sub-image of the green field.

Detailed Description Text (50):

In display systems for sequentially formed composite images, the display image data is transferred to the display matrix from a frame buffer. The frame buffer is

typically external to the display system in the sense that the frame buffer is a separate component from the display matrix.

Detailed Description Text (51):

The purpose of an external frame buffer is to house an entire frame of data and act as an intermediary between some sort of processor, which initializes and modifies the image in the frame buffer, and the display matrix, which displays the image or part thereof. The data transfer bandwidth between the processor and the frame buffer varies according to the rate of change in the content of the image. For example, a static, monochromatic image requires essentially zero bandwidth. In a display system operating in an FSC mode with a high frame rate, the bandwidth requirement remains high regardless of how static the image may be.

Detailed Description Text (52):

A display matrix of the present invention can also be used to store multiple sub-images, for example all the sub-images of a single color field as opposed to an entire frame. For example, with three memory cells in each display element, the memory cells can be assigned to the MSB, SSB, and LSB sub-images of a color field, for a total number of $2^{\text{sup.}3} = 8$ shades of gray. If the memory cells are then reassigned to corresponding sub-images of the next color field during the display of the next color field, then 8 levels of grayscale will be possible for the next color field as well. For an entire frame, a total of $8^{\text{sup.}3} = 512$ colors are possible.

Detailed Description Text (53):

Using a display matrix of the present invention operated in an FSC mode, it is possible to house an entire frame of data in the display matrix itself. For example, a three color FSC system may be built from a display matrix having three memory cells in each display element. Each memory cell would be dedicated to a different color field sub-image. Since there would only be one bit per field, the total number of colors possible in the system would be $2^{\text{sup.}3} = 8$. With six memory cells in each display element, $4^{\text{sup.}3} = 64$ colors would be possible.

Detailed Description Text (54):

The advantage of housing an entire frame of data within the display matrix is that the external frame buffer may be completely eliminated from the display system, saving not only a component but also a great deal of bandwidth. Only the bandwidth between the processor and the display matrix would remain. In contrast, operating a prior art display matrix in FSC mode, there is no room within the display matrix to house multiple sub-images simultaneously, necessitating an external frame buffer.

Detailed Description Text (55):

One condition for eliminating the external frame buffer is that the display matrix behave like an external frame buffer from the processor point of view. In particular, the display matrix should behave like a memory: random access addressable as well as readable and writable. In contrast, the display matrix of prior art typically is not random access addressable and is only writable.

Detailed Description Text (56):

The primary interface to the display matrix from the source of image data can mimic that of a synchronous SRAM. For example, the clocked interface includes a general backplane IC chip select and a read/write signal. An internal write buffer supports consecutive writes to the memory cells in the display matrix and to programmable registers outside the display matrix. The latency to the first read data from either the memory cells or the programmable registers is a fixed number of cycles. Data on consecutive cycles is returned on burst reads. The length of burst accesses can be programmed to be 1, 2, 4, or 8 words, where the length of a word is defined as the data bus width. The latter is initialized to 8 bits on reset, but can be reprogrammed to 8, 16, or 32 bits. A total of 20 address lines can be used to specify the destination of a read or write to the memory matrix.

Detailed Description Text (57):

A secondary interface optimized for minimum pin count is also possible. The secondary interface can include a vertical synchronization signal, a horizontal synchronization signal, a data enable signal, and a clock, along with 8, 16, 24, 32, or some other intermediate number of bits of data. The secondary interface can be used to scan data into the display matrix only, with no capability to read data from the matrix.

Detailed Description Text (58):

A variety of actual sources of image data outside the display matrix may be used. For instance, read only memory (ROM), programmable memory such as a field programmable gate array (FPGA), an external frame buffer, or a processor are possible.

Detailed Description Text (59):

Modes of Operating The Display Matrix

Detailed Description Text (60):

Several different modes for operating a display matrix according to the present invention are possible. One mode, referred to herein as the "Power Miser Mode," relates to a mode where writing to the display matrix is minimized, there reducing the amount of energy consumed by the display matrix. Another mode of operation, referred to herein as the "Color Rich Mode," relates to a mode where data is written to memory cells forming one bit plane while memory cells of another bit plane are used to display an image in order increase the number of sub-images that can be used to form a composite image. By being able to increase the number of sub-images that can be used to form a composite image, a greater number of colors may be formed by the display matrix. Yet another mode of operation, referred to herein as the "Color Mixing Mode," involves operating a display matrix in a Power Miser Mode and Color Rich Mode at the same time.

Detailed Description Text (61):

While the Power Miser, Color Rich, and Color Mixing modes for operating a display matrix according to the present invention are provided below, it is noted that many additional modes of operating the display matrices can be employed.

Detailed Description Text (63):

One mode of operating a display matrix according to the present invention is illustrated in FIG. 9 in which a processor 54 interfaces directly with the display matrix (backplane IC) 42. This mode is referred to herein as power miser mode because the image is initialized and modified directly in the display matrix memory without the use and associated power consumption of an external frame buffer. Because the backplane IC is fundamentally digital in nature, component and power consumption costs associated with digital-to-analog converters or other analog circuitry is avoided.

Detailed Description Text (64):

In operation, the backplane IC offers several functions in support of power miser mode. The synchronous SRAM interface on the chip coincides with the memory model assumed by typical processors. By using three memory cells per display circuit, the chip also offers capacity for a red, a green, and a blue bit plane, the minimum necessary for a display matrix to operate in an FSC mode. The chip can also be programmed for FSC control, a sequence such as the following:

Detailed Description Text (71):

In an eight-level grayscale monochrome implementation of power miser mode, the RED, GREEN, and BLUE cells of each display circuit are filled with the MSB, SSB, and the LSB of the corresponding image data. The three bit planes can be strobed in a variety of time modulation schemes to achieve the eight levels of grayscale in the

color of the single illumination source. One possibility is to strobe the bit planes in RMS fashion using distributed binary coding as described later.

Detailed Description Text (73):

FIG. 10 illustrates an address map including scroll buffers. The address bus illustrated in the figure is 20 bits wide. Bits A.sub.6 through A.sub.0 specify column address of a byte, A.sub.16 through A.sub.7 its row address, and A.sub.18 through A.sub.17 its bit plane address. This address scheme assumes the three SRAM cells in each display element have been configured for separate address (WORD) signals. The address space of the display matrix encompasses 0-99 in the column address, 0-599 in the row address, and 0-2 in the bit plane address. Bit A.sub.19 is the programming bit.

Detailed Description Text (80):

Scrolling is an example of hardware assistance for a graphical operation that is outside the operation of display matrices of prior art. By subsuming the external frame buffer within the display matrix of the present invention in power miser mode, a wide variety of hardware assistance functions for image modification become possible and useful within the display matrix.

Detailed Description Text (82):

A second mode of operating a display matrix according to the present invention is illustrated in FIG. 11, in which an external frame buffer 56 is placed between the processor 54 and the display matrix (backplane IC) 42. This mode is referred to herein as color rich mode, because the multiple bit planes in the display matrix are used to generate multiple levels of grayscale in each of the color fields. For example, when three bit planes are used, eight levels of grayscale (2.sup.3) are produced in each of three color fields for a total of 512 colors (8.sup.3) in FSC operation.

Detailed Description Text (85):

Transfer the MSB, 2.sup.nd SB, and LSB bit planes of the red image into the RED, GREEN, and BLUE memory planes of the display matrix.

Detailed Description Text (90):

Transfer the MSB, 2.sup.nd SB, and LSB bit planes of the green image into the BLUE, GREEN, and RED planes of the display matrix.

Detailed Description Text (95):

Transfer the MSB, 2.sup.nd SB, and LSB bit planes of the blue image into the RED, GREEN, and BLUE planes of the display matrix.

Detailed Description Text (102):

One algorithm that has been found empirically to have a better RMS effect than the above conventional coding scheme for a particular LCD is called distributed binary coding. A better RMS effect refers to the gradation in voltages driven on the liquid crystal being more uniform. The strobing formula for distributed binary coding is {MSB, SSB, MSB, LSB, MSB, SSB, MSB}. For example, 0={0000000}, 1={0001000}, 2={0100010}, 3={0101010}, 4={1010101}, 5={1011101}, 6={1110111}, and 7={1111111}. In FIG. 12, distributed binary coding is used to display a grayscale 3 in the red field followed by a 6 in the green field.

Detailed Description Text (103):

While the above formula relates to the present invention with three bit planes, distributed binary coding can be extended to display matrices of any number N of bit planes. The interval is first always divided into (2.sup.N - 1) time slots. The MSB plane time slots are determined first. The MSB plane is always placed in the first time slot and every other time slot thereafter. The 2.sup.nd SB plane time slots is calculated next. The SSB plane is placed in the first available time slot and every fourth time slot thereafter. The 3.sup.rd SB occupies the next available

time slot and every eighth slot thereafter, and so on until the LSB (N.sup.th) plane is place in the middle time slot. For instance, for four bit planes, the formula is {MSB, 2.sup.nd SB, MSB, 3.sup.rd SB, MSB, 2.sup.nd SB, LSB, MSB, 3.sup.rd SB, MSB, 2.sup.nd SB, MSB}.

Detailed Description Text (104):

The ability of the display system of the present invention to perform distributed binary coding is a strong example of one of the advantages that the display circuit of the present invention provides. The grayscale level is strobed twice in one color field, once in the RECOVERY period and once in the ACTIVE period, for a total of 14 time slots. In a system with only one memory cell per display circuit, fourteen bit planes would have to be loaded in in order to strobe during 14 different time slots. This would require a very high bandwidth transfer rate and pixel refresh rate. However, by using a display matrix capable of storing three different bit planes, different bit planes need not be continuously written into a display matrix. This allows strobing the transition between strobing different bit planes to be significantly reduced, thereby making it possible to have 14 time slots.

Detailed Description Text (105):

According to the present invention, it is possible to alternate the assignment of MSB memory matrices for consecutive color fields. This enables the display matrix to further take advantage of having more than one memory cell in each display circuit. For instance, in the above sequence, the {RED, GREEN, BLUE} memory matrices were assigned to {MSB, SSB, LSB} for the RED field, while in the ensuing GREEN field, the assignments were switched to {LSB, SSB, MSB}. This algorithm is driven by the nature of distributed binary coding, in which the LSB plane always falls in the middle time slot while the MSB plane is always at the beginning. Once the LSB plane for the ACTIVE period of the RED field has completed, the memory plane can be used for the first plane needed by the GREEN field, which is the MSB plane. Hence, by modifying the assignment of the bit planes as MSB, SSB and LSB, etc., it is possible to increase the number of bit planes which can be written to memory and strobed.

Detailed Description Text (106):

Distributed binary coding and the accompanying strategies discussed above have been found empirically preferable for certain liquid crystal formulations. Other algorithms may be better suited for other display matrices and are intended to fall within the scope of the present invention.

Detailed Description Text (110):

A third mode of operating a display matrix according to the present invention, referred to herein as color mixing, relates to the overlay of a color rich region on a power miser background. This mode of operation is illustrated in FIG. 13. By combining color rich operation with power miser operation, a window of high information content can be formed without incurring the bandwidth and power consumption costs associated with full-screen color rich operation. The reduction in bandwidth requirements improves the compatibility of the display matrix with video applications.

CLAIMS:

1. A display matrix comprising:

a plurality of display elements, each display element including

a pixel;

a display circuit electrically connected to the pixel, the display circuit including

a plurality of SRAM memory cells, and

a selector continuously electrically connected to more than one of the plurality of memory cells, the selector outputting to the pixel data from one memory cell at a time; and

peripheral control circuits electrically connected to the memory cells, the peripheral control circuits reading data from the memory cells, modifying the data, and writing the modified data to the memory cells.

2. The display matrix according to claim 1 wherein the memory cells include at least 3 memory cells.

3. The display matrix according to claim 1 wherein the memory cells include at least 9 memory cells.

4. The display matrix according to claim 1 wherein the reading, modifying and writing of data by the peripheral control circuits provides a cursor function to the display matrix.

5. The display matrix according to claim 1 wherein the reading, modifying and writing of data by the peripheral control circuits provides scroll function to the display matrix.

6. The display matrix according to claim 1 wherein the pixels form a liquid crystal display.

7. The display matrix according to claim 6 wherein the reading, modifying and writing of data by the peripheral control circuits provides an inversion function to the liquid crystal display matrix.

8. The display matrix according to claim 1 wherein peripheral control circuits include programmable registers that modify the read data.

9. The display matrix according to claim 1 wherein the display circuit includes one or more inputs for controlling the operation of the selector.

10. The display matrix according to claim 1 wherein the display circuit can be operated in a field sequential color (FSC) mode without having to write to the memory cells between displaying different fields.

11. The display matrix according to claim 1 wherein the display matrix does not have an external frame buffer.

12. The display matrix according to claim 11 wherein the display matrix can be operated in a field sequential color (FSC) mode without having to write to the memory cells between displaying different fields.

13. The display matrix according to claim 1 wherein the display matrix can be operated in a field sequential color (FSC) mode where a first set of memory cells defining a first bit plane are written to while a second set of memory cells defining a second bit plane are used to display a sub-image.

14. The display matrix according to claim 1 wherein an assignment of sub-images to different memory cells may be performed dynamically.

15. The display matrix according to claim 1 wherein the pixels of the plurality of display elements form a source object having an area equal to or less than about 400 mm.^{sup.2}.

16. The display matrix according to claim 1 wherein the pixels of the plurality of display elements form a source object having an area between about 20 mm.sup.2 and 100 mm.sup.2.

17. The display matrix according to claim 1 wherein the pixels have an area less than about 0.01 mm.sup.2.

18. The display matrix according to claim 1 wherein the pixels have an area between about 50 .mu.m.sup.2 and 500 .mu.m.sup.2.

19. The display matrix according to claim 1 wherein the pixels are spatial light modulators.

20. The display matrix according to claim 1 wherein the pixels are light emitting elements.

21. The display matrix according to claim 1 wherein the display matrix is a component of a device selected from the group consisting of portable computers, personal communicators, personal digital assistants, modems, pagers, video and camera viewfinders, mobile phones, and television monitors.

22. A display matrix comprising:

a plurality of display elements, each display element including

a pixel;

a display circuit electrically connected to the pixel, the display circuit including

a plurality of SRAM memory cells, and

a selector permanently electrically connected to each of the plurality of memory cells, the selector outputting to the pixel data from one memory cell at a time; and

peripheral control circuits electrically connected to the memory cells, the peripheral control circuits reading data from the memory cells, modifying the data, and writing the modified data to the memory cells.

23. The display matrix according to claim 22 wherein the display matrix further includes a plurality of conductive elements, each conductive element electrically connecting a single member of the plurality of memory cells to the selector.

24. A display matrix comprising:

a substrate;

a plurality of pixels;

a plurality of display circuits, each display circuit positioned on a different region of the substrate, each display circuit electrically connected to a different pixel, each display circuit including

a plurality of SRAM memory cells, and

a selector connected to each of the plurality of memory cells, the selector outputting to the pixel data from one memory cell at a time; and

peripheral control circuits electrically connected to the memory cells, the peripheral control circuits reading data from the memory cells, modifying the data, and writing the modified data to the memory cells.

25. A display matrix comprising:

a plurality of display elements, each display element including

a pixel;

a display circuit electrically connected to the pixel, the display circuit including

a plurality of SRAM memory cells, and

a selector electrically connected to the plurality of memory cells for outputting to the pixel data from one memory cell at a time; and

peripheral control circuits electrically connected to the memory cells, the peripheral control circuits reading data from the memory cells, modifying the data, and writing the modified data to the memory cells;

wherein the memory cells are physically interdispersed among the selectors within the plurality of display elements.

26. A display system comprising:

a display matrix including a plurality of display elements, each display element including a pixel for forming a portion of a source object, a display circuit electrically connected to the pixel, the display circuit including a plurality of SRAM memory cells, and a selector continuously electrically connected to more than one of the plurality of memory cells, the selector outputting to the pixel data from one memory cell at a time;

peripheral control circuits electrically connected to the memory cells, the peripheral control circuits reading data from the memory cells, modifying the data, and writing the modified data to the memory cells;

a processor for controlling an operation of the peripheral control circuits.

27. The display system according to claim 26, further including a light emitting mechanism provided at each pixel.

28. The display system according to claim 26, further including a light modulating mechanism provided at each pixel.

29. The display system according to claim 28, further including an illumination source for illuminating the pixels.

30. The display system according to claim 28, wherein the said light modulating mechanism is a liquid crystal material.

31. The display system according to claim 26 wherein the reading, modifying and writing of data by the peripheral control circuits provides a cursor function to the display matrix.

32. The display system according to claim 26 wherein the display system is capable of composing a bit mapped image without the need of an external frame buffer.

33. The display system according to claim 26 wherein the reading, modifying and

writing of data by the peripheral control circuits provides a scroll function to the display matrix.

34. The display system according to claim 26 wherein the pixels form a liquid crystal display and the reading, modifying and writing of data by the peripheral control circuits provides an inversion function to the liquid crystal display matrix.

35. The display system according to claim 26 wherein the display system further includes an illumination source capable of providing a plurality of different color illumination to the pixels, the particular color illumination provided to the pixels being coordinated by the peripheral control circuits with the read and write operations to the memory cells.

36. The display system according to claim 26, further including an illumination source which provides at least three different colors of illumination.

37. The display system according to claim 26 wherein the display system is a component of a device selected from the group consisting of portable computers, personal communicators, personal digital assistants, modems, pagers, video and camera viewfinders, mobile phones, and television monitors.

38. A virtual image display system comprising:

a display matrix including a plurality of display elements, each display element including a pixel for forming a portion of a source object, and a display circuit electrically connected to the pixel, the display circuit including a plurality of SRAM memory cells, and a selector continuously electrically connected to more than one of the plurality of memory cells, the selector outputting to the pixel data from one memory cell at a time;

peripheral control circuits electrically connected to the memory cells, the peripheral control circuits reading data from the memory cells, modifying the data, and writing the modified data to the memory cells; and

one or more magnification optics for magnifying images formed by the display matrix.

39. The virtual image display system according to claim 38 wherein the display system is a display component of a device selected from the group consisting of portable computers, personal communicators, personal digital assistants, modems, pagers, video and camera viewfinders, mobile phones, and television monitors.

40. A method for manipulating data initially stored in a display matrix which includes a plurality of display elements, each display element including a pixel, and a display circuit electrically connected to the pixel, the display circuit including a plurality of SRAM memory cells and a selector continuously electrically connected to more than one of the plurality of memory cells, the method comprising the steps of:

reading data from the memory cells to peripheral control circuits electrically connected to the memory cells;

modifying the data using the peripheral control circuits; and

writing the modified data to the memory cells.

41. The method according to claim 40 wherein reading, modifying and writing of data by the peripheral control circuits provides a cursor function to the display matrix.

42. The method according to claim 40 wherein reading, modifying and writing of data by the peripheral control circuits provides a scroll function to the display matrix.

43. The method according to claim 40 wherein the pixels form a liquid crystal display and reading, modifying and writing of data by the peripheral control circuits provides an inversion function to the liquid crystal display matrix.